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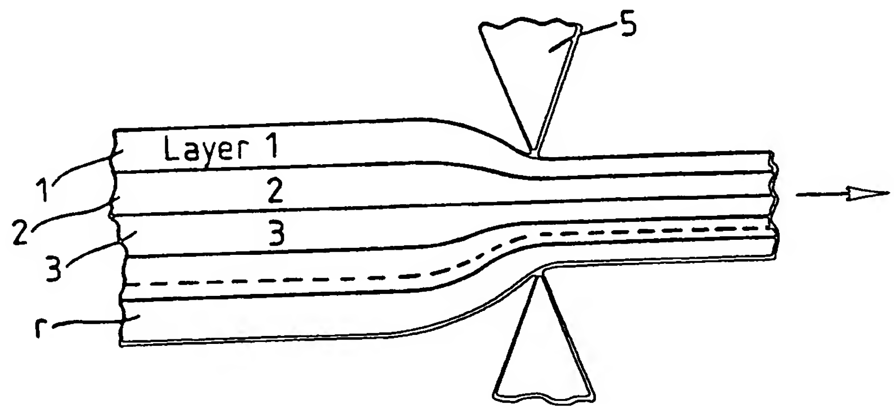
(54) **Optical interference filters**

(57) A multi-layer optical interference filter consists of a plurality of layers 1, 2, 3...r of polymer material. The layers may each be formed by solvent coating operations or dip coating techniques. To reduce the thickness of the multi-layer stack it can be drawn through a die 5.

FIG. 2



At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

GB 2 232 498 A

FIG. 1

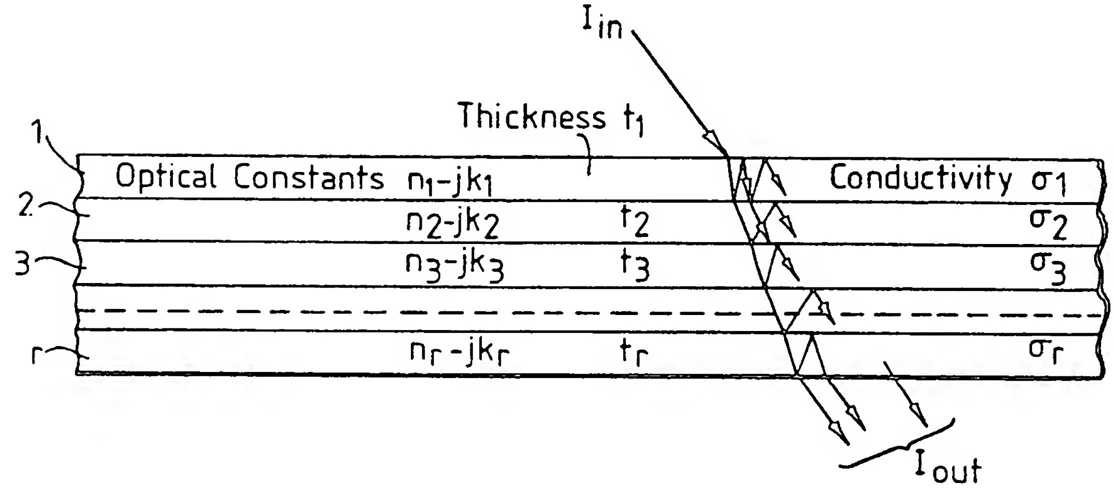
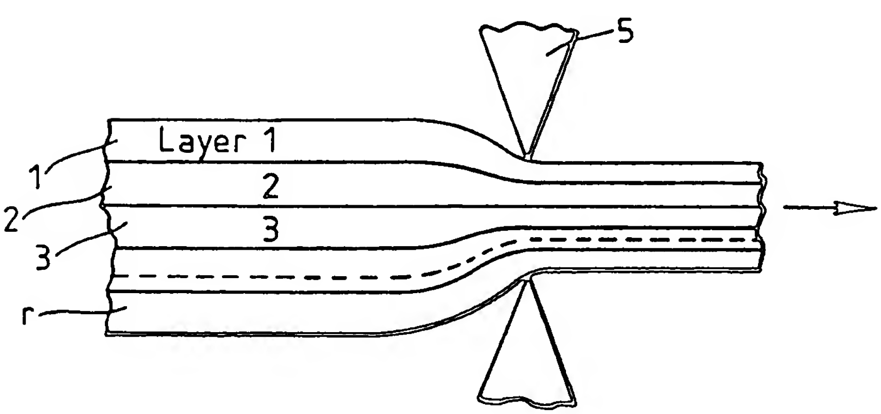

I_{in}
Thickness t_1
1
Optical Constants $n_1 - jk_1$
Conductivity σ_1
2
$n_2 - jk_2$
t_2
σ_2
3
$n_3 - jk_3$
t_3
σ_3
r
$n_r - jk_r$
t_r
σ_r
I_{out}

FIG. 2


5
Layer 1
2
3
1
2
3
r

P/8016/MRC

Optical Interference Filter

This invention relates to optical interference filters.

Such filters are, in general, made up of a number of layers of materials of differing refractive indices. The sequence of layers, their thicknesses and optical constants (refractive index and extinction coefficient) are chosen to give the required reflection and/or transmission characteristics, which mainly arise due to multiple reflections at the interfaces between layers of differing optical constants.

Such filters are generally fabricated by thin film deposition of inorganic materials to form the various layers sequentially on a substrate. However, this technique is subject to a number of disadvantages. Thus, large area filters are difficult to make because such filters require a large and expensive film deposition equipment and it is difficult to control uniformity of thickness over the whole area. Also, because each layer is deposited separately using vapour deposition techniques, it is not possible to incorporate electro-active materials since these require a high level of atomic or molecular ordering. Also, such filters are relatively expensive to manufacture.

The invention provides a multi-layer optical interference filter having at least one layer of polymer

material.

The invention also provides a method of making the multi-layer optical interference filter comprising forming a stack of layers, at least one of which is a polymer material.

The use of a layer of a polymer material facilitates fabrication of the interference filter.

The or each polymer layer may be made during a solvent casting operation, or alternatively, a number of free-standing films extruded through a die may be employed.

An optical interference filter together with a method of manufacturing the filter will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a schematic view of an interference filter; and

Figure 2 illustrates a stage in the manufacture of the filter.

Referring to Figure 1, the optical interference filter consists of layers 1, 2, 3, r having refractive indices n_1 to n_r, extinction coefficient k_1 to k_r, thickness t_1 to t_r and conductivity O_1 to O_r. The optical characteristics of the filter are largely determined by multiple internal reflections between the individual layers. For example, the layers for example, four, may alternate between a low and a high value of refractive

index.

In accordance with the invention, the layers are all made of polymer material.

The layers may each be formed by solvent coating operations using spin coating or dip coating techniques. The first layer is coated onto a substrate and subsequent layers are coated onto the previous layer and, when the stack has been completed, the substrate is removed.

In a particularly useful alternative, referring to Figure 2, the optical filter consists of free-standing polymer films secured together using either adhesive interlayers or using the self-adhesive properties of the films themselves. Any number of films may be secured together in this way.

Some or more of the films may be rendered active to an external stimulus, eg where its optical properties are desired to be modified by an external stimulus such as an electric field, temperature, pressure etc, prior to incorporation in the stack. Some of the layers may be electro-active: in this case the two adjacent layers may be electric conductors with suitable optical properties, or a pair of electrodes covering the whole stack may suffice.

In order to reduce the thickness of the multi-layer stack, it is extruded or drawn through a die 5. For example, the stack may consist of films of 3 microns thickness. When extruded, they may each be reduced in

thickness by a factor of five. Since a quarter wave length filter for the visible region may be 0.1 microns thick, and filters built of a multiple of quarter wavelengths e.g. 5 quarter wavelength may also have useful optical properties, filters having layers which are optically useful will result after the extrusion process. In contrast, the films having a thickness of 3 microns are too thick to provide useful optical properties when made into a stack.

The films which are together extruded must be compatible, for example, they must possess similar mechanical properties. Suitable polymers are the methacrylates.

If it is found that after extrusion, some of the films are compressed too much relative to the others, this can be compensated for by providing a thicker film for that layer before extrusion.

If desired, any of the electro-active layers may be poled, that is, a preferred orientation of active molecular groups may be induced by an electric field, which orientation is subsequently locked in, by external electrodes, or by using those embodied in the sequence of the stack. The poling may either be done in the stack, or prior to incorporation in the stack if the subsequent processing does not effectively destroy the induced alignment.

The stack may consist of any number of layers. The

layers may be alternately high and low refractive indices, for example, around 1.7 and around 1.4, to form a multi-layer dielectric stack (which acts as a reflector) as described on p. 164 of Optical Filters by H. A. MacLeod.

CLAIMS

1. A multi-layer optical interference filter having at least one layer made of polymer material.

2. A filter as claimed in claim 1, in which the or each polymer layer is made by a solvent casting operation.

3. A filter as claimed in claim 1, in which the or each polymer layer is a free-standing film.

4. A filter as claimed in claim 3, in which the thickness of the filter has been reduced by a passage through a die.

5. A filter as claimed in claim 3 or claim 4, in which an electro-active polymer layer has been poled.

6. A multi-layer optical interference filter substantially as hereinbefore described with reference to the accompanying drawings.

7. A method of making a multi-layer optical interference filter comprising forming a stack of layers, at least one of which is made of a polymer material.

8. A method as claimed in claim 7, including the step of casting a polymer layer from a solvent.

9. A method as claimed in claim 7, including the step of employing a free-standing polymer film in the stack.

10. A method which includes reducing the thickness of the multi-layers stack by passing the stack between the jaws of a die.

11. A method as claimed in any one of claims 7 to 10, in which at least one electro-active optical layer has been

poled.

12. A method of making a multi-layer optical interference filter substantially as hereinbefore described with reference to the accompanying drawings.

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